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THE BIOLOGY OF THE NET-SPINNING TRICHOPTERA OF CASCADILLA CREEK.*

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CONTENTS.

I. Introduction.

The net-spinning Trichoptera are confined to the members of the old Family Hydropsychidæ, which has been subdivided (Ulmer 1909) into four families, Hydropsychidæ, Philopotamidæ, Polycentropidæ, and Psychomyidæ. Nets of some of the genera of the first three families have been described, but as far as is known, larvae of the Psychomyidæ spin no catching-nets. (Wesenberg-Lund, 1911). The only nets described in this country up to this time have been of the genus Hydropsyche. Most of the work on the catching-nets has been done within the last six years and almost entirely by Danish investigators.

Contribution from the Limnological Laboratory of Cornell University.

This paper is a preliminary study of the net-spinning Trichoptera of Cascadilla Creek with special reference to the nets—the method of construction, their efficiency as a plancton-catching apparatus, and the closely related problems of food and feeding habits.

Since the net-spinning caddis-worms are found in still as well as swift flowing water, and their nets are such interesting and beautiful structures, it seems strange that they should have been overlooked for so long a time. I have found nets representing some of the genera of the families Hydropsychidæ, Philopotamidæ, and Polycentropidæ, and will treat them by families in that order. In each family I have first given extracts or a brief summary of the work published on the nets up to this time and have then added my own observations.

This work was carried on under the supervision of Prof. James G. Needham, to whom I am especially grateful for his valuable suggestions and encouragement at all times.

II. Catching-nets of the Families Hydropsychidae, Philopotamidae, Polycentropidae.

Family Hydropsychidæ.

The first description of a catching-net is found in Dr. F. Muller's work (1881). He describes and figures the net of one of the Hydropsychidæ, a southern Brazilian sp. of the Genus Rhyacophylax. He always found the houses on the upper side of stones, made of irregularly interwoven plant fibres or of small stones. Each house has a funnel-shaped vestibule or verandah, whose sidewalls are generally constructed out of interwoven fibres. These serve as a covering for a very delicate silken net with square meshes, generally from 0.2 to 0.3 mm. in diameter. The entrance to the vestibule is always directed up stream, so that the water coursing through it catches and holds back organisms which serve as food for the caddis-worm. The larvae rarely live alone, but generally construct their houses very close to one another so that sometimes continuous rows of them are formed.

In the year following, the first work on the nets of the Genus Hydropsyche appeared in this country in an article by Miss Cora Clarke. In a later paper, 1891, she mentions these larvae and their nets again, but gives no additional data.

To quote from the first article: "The typical form of the structure resembles a tunnel attached to the surface of a stone, having at its mouth a vertical framework with a net stretched across it. An open mouth or entrance to the case is always close to this net on the side towards the current, so that without wholly leaving its house the larva can remove from the net anything eatable, which the current may have lodged there. The mode of building varies considerably. The case is usually about half an inch long and a little curved, loosely attached to the stone by its edges and without any bottom. It may be composed entirely of sand or of bits of plants or both combined. The supporting framework of the net is always formed of vegetable bits, and is sometimes a simple arch, sometimes a complete ring, and sometimes a short cylinder. It is occasionally stayed or held in position by silken cords stretching from it to suitable points on the stone. It is stiff enough to stand erect even when removed from the water. When it is in the shape of a cylinder or broad arch the net is always stretched across that end of it which is down stream and the entrance usually opens under the shelter of the arch. * * * * In a stream in Brookline, Mass., are large communities of these larvae. The stones in the stream are covered with mud, leaves and rubbish.

Sometimes a stick which has fallen into the brook has a row of cases and nets built upon it. Often a stone will have a row of them side by side along one edge, or there may be only a few of these structures scattered separately upon its surface." She mentions having received a net and larva from Mt. Desert, Me.

In 1886 L. O. Howard found similar nets of a Hydropsyche larva on the Simulium-covered rocks in the swift water of Rock Creek, near Washington. "The cases varied greatly in size, the mouth of the funnel in some instances not more than 3 mm. in diameter and in others reached fully 10 mm. The tube of the funnel was in every case bent at nearly right angles with the mouth and the larva ensconced within it waited for its prey to be caught in the broadened mouth.

The broad funnel-shaped expansion was woven in fine meshes with exceedingly strong silk and was supported at the sides and top by bits of twigs and small portions of stems of water plants. The central portion was so open as to allow the water to pass through readily."

In 1888 the same author mentions finding the larvae in a similar situation in Ithaca, the nets and cases being very abundant on the Simulium-covered rocks. "The nets differed from those found at Washington and the species is probably different."

In his Insect Book (1901) we find the following: "The cases were preferably placed at the edge of slight depressions in the rocky surface so that the tubular portion was protected from the full force of the current. On the surface of a rock about 18 inches in diameter 166 of these nets were counted."

Adele M. Fielde (1887) writes from Swatow, China, of a net similar to those previously described. "During last January I found on the level surface of the coarse sand which covers the bottom of an aqueduct near here, under an inch or two of clear running water, little structures resembling a gray net spread to catch fish or a tiny cave with a gauze awning stretched over the entrance. The arches had a span of from an eighth to half an inch and always opened towards the current. They were to be seen in scores with a buttress of coarse sand in the rear, and a minute aperture in the floor. The occupant of the wee grotto was in every case a caterpillar not more than five-eighths of an inch long. It burrowed in the sand of the floor, stretched its head forth vertically, and fed upon what had been caught in the delicate roof of its den."

Comstock, J. H., (1895) in speaking of Hydropsyche larvae says: "Stretched between two stones near by can be seen his net. This is made of silk. It is usually funnel-shaped, opening up stream; and in the center of it there is a portion composed of threads of silk extending in two directions at right angles to each other, so as to form meshes of surprising regularity. These nets occur in rapids between stones, but in many places they are to be found in greater numbers along the brinks of falls. Here they are built upon the surface of the rock, in the form of semi-elliptical cups, which are kept distended by the current. Much of the coating of dirt with which these rocks are clothed in summer is due to its being caught in these nets."

Betten, C. (1901), says of a Hydropsyche sp. (near phalerata, Hagen), that there was "no larval case, only strands of silk between the rocks."

Comstock, Anna B., (1903), in describing the snare of Hydropsyche writes, "It is formed like a dip-net and fastened with silk to a frame of leaves or pebbles, so that its distended mouth is directed up stream. Near the frame it consists of fragments of vegetation woven into a silken tapestry and is finished at the end with a bag of coarse, even mesh. The regularity of this bit of netting is beautiful to behold, and its use shows the cleverness of the builder. This large mesh allows the water to flow through freely, and thereby leave entangled in the seine any little creature not small enough to pass through. * * * On the side of this tiny seine toward the current of the stream is a little passage which leads to the seine-builder's house."

The work on the net-spinning Trichoptera was next taken up in Europe and it is to the Danish investigators that we owe our most extended knowledge of the various kinds of nets, and whose work stimulates a desire to carry their efforts farther. E. Petersen, in 1908, found the catching nets of Hydropsyche instabilis in a brook north of Silkeborg (Denmark). The larger stones were completely covered with Potamogeton pectinatus, Fontinalis antipyretica and Jungermannia sp., and on them the trumpet-shaped catching nets were placed in rows and connected with one another. The nets were small, being only 8-10 mm. in diameter at the mouth, and their depth about 7 mm. The nets were always supported by the plants and parts of these were often woven in. In many cases one net was placed a little behind the others and connected with them by a strong web. At the base of the net lurked the larva.

In 1909 Ussing described a catching-net of H. instabilis that he had found in Hornbek brook in the vicinity of Randers. Being unable to obtain this paper, I have translated an extract from it, which was quoted in Wesenburg-Lund's (1911) article. "The nets are placed obliquely in front of the opening of the larva's tunnel, built of very fine, square meshes (0.2 mm. in diameter), propped up by bits of plants. The dwelling of the larva is built out of mud and half decayed fragments of plants; the tube is spun fast to a stone on the bottom of the brook. I have often found whole rows of these dwellings with nets placed between the separate occupants. The nets turn their expanse against the stream, which is always very

swift and in spite of their delicate construction, they stand the considerable pressure of the water very well. I have never noticed that the dwellings or nets protruded above water."

One of the most interesting of the descriptions of Hydropsyche catching-nets comes from Dr. Wesenberg-Lund. In his paper (1911) he has compiled the records of all known cases of net-spinning and extended our knowledge greatly by personal observations. He studied the nets of H. pellucidula and H. angustipennis, and gives a very full description of the beautiful structures of the latter which he studied in July, 1909, in the outlet of Foenstrup pond in Gripwalde. The larvae had utilized the leaves of Lemna triscula in the construction of their dwellings, and chains of these, arranged in rows, were placed obliquely across the stream. Every chain was composed of the dwellings of a number of larvae. Each house had a funnel-like entrance facing up stream which led into a vestibule about 1-2 cm. long and of the same height, covered with Lemna leaves. In the farther corner was the entrance to the larval dwelling which was 2-3 cm. long. This is always laid obliquely to the principal course of the chain, and was made of small bits of decayed wood and pebbles interwoven in the silken mesh and covered with Lemna leaves. In the wall of the vestibule towards the entrance to the dwelling was a circular window about 1 cm. in diameter covered by a beautiful screen. This served as the larva's catching-net and was woven of strong threads crossing nearly at right angles and of wonderful regularity in the centre, but irregular and of a coarser mesh toward the framework, which was made of small pieces of straw finely fastened together. The cases were submerged in the water, but the upper part of the vestibule and window projected over the surface of the water. I have copied a diagramatic figure of a Hydropsyche house from his paper. (See Plate XXXVII, Fig. 1).

In regard to the seasons when the nets are found he gives the following data: "Up to December, beautiful larval dwellings and nets are found; from December to the last of April no nets observed. During this period the larvae were found rolled up under stones or in crevices in boards, probably taking only a little food. At the beginning of May and during the whole of June the nets were put up again."

His observations agree completely with those sent him by Ussing, who made regular observations on the nets of H. instabilis during the winter of 1909-10 at "Hornbek brook." "On the 24th of October, 1909, the nets were very numerous; on November 7, beautiful catching nets; on January 2, and January 19, 1910, none. The animals build no catching-nets in winter. The larvae lie rolled up in a spiral and are not active, moving reluctantly. They do not live in the usual case, but in an irregular net with small pebbles interwoven. He believes that the Hydropsyche larvae lie in a dormant condition and take no food in winter.

My observations were started the latter part of October, 1912, and at this time, although the nets were numerous everywhere in the creek, they were inconspicuous, owing to a thick coating of diatom ooze and silt, and they were badly torn by the large numbers of fallen leaves swept along by the current. Only rarely during November did I find a perfect net, and during the winter months no nets at all. Heavy rains the last week in March made any observations impossible, as the turbid water rushed along in torrents. On my next visit, however, on April 12, it was as if the stones had been touched by some magic wand, for nets had sprung up everywhere. They were found on the upper surface of stones or shelving rocks wherever there were irregularities or crevices against which the cases might be built; on submerged twigs, on the underside of stones, and between stones on the bottom. The nets were also thick along the edges of the stream, many distended pockets being found in the tangle of roots which floated out into the current. In July similar nets were observed in the mats of Cladophora, but these were generally the tiny pockets of very young larvae. I could find no definite dwelling tube in either of these instances, but the larvae were found crawling among the roots or algal filaments.

On the brinks of the waterfalls were rows of vertically placed nets, so that a continuous stream of water was pouring down their open mouths. On the creek bottom the nets were generally fastened between two stones, some being of the "dip-net" type, while others formed a horizontal net. In both instances, however, the net was composed of coarse, irregular mesh at its entrance and a fine regular mesh behind.

Although there are six species of Hydropsyche larvæ common in Cascadilla Creek, I have not been able to find any specific differences in their nets, so will describe them collectively. The case in which the larva lives, I found as described by others, except Miss Clarke, to be made of vegetable bits, pebbles, or a combination of both woven into an irregular cylindrical tube. In front of this, opening toward the current is a net. Mrs. Comstock's word "dip-net" best describes its shape. Beginning at the entrance and generally extending for a little more than one half the depth of the net is a very irregular, coarse silken mesh, the bottom of the net being composed of a wonderfully beautiful, regular mesh. This latter is the catching surface proper from which the larva feeds. The tube in which it lives extends a very short distance into the net, so that its entrance opens under the fine mesh. The tube opens into the net either from the right or left side, and is found either extending back in a straight line with the net or almost at right angles to it. When the stones are taken from the water, some of the nets stand upright owing to the supports of plant tissue woven into the coarse mesh. Sometimes there is a complete supporting arch, but often there is only an oblique prop on either side, anchored to the stone by silken guy lines. The threads of the catching surface are somewhat distensible, and when seen in the water it is concave, but when removed, it appears as a flat, almost circular disc in its supporting framework. In many cases, however, the nets collapse completely when there is no current to distend them, there being no supporting bits of any description. See Plate XXXVII, fig. 2. In summer many of the nets have long green streamers of Cladophora filaments, which have become entangled in the nets and float back several inches behind them.

The average expanse of the nets at the entrance is about 8 mm. although some of the largest ones have an expanse of 20 mm., with a depth of 15 mm., while those of the very young larvæ have an expanse of 1½ to 2 mm. and a depth of 1 mm. These nets and dwellings I have always found completely submerged, and the true catching surface placed at the end of the vestibule, instead of in its sidewall as in that of H. angustipennis described by Wesenberg-Lund (1911). The threads are very firm so that they may withstand the force of the current and there is no difficulty in seeing the meshwork with the naked eye.

Family Philopotamidæ.

The only descriptions of catching nets of this family are those of Thienemann. He gave a brief account of a net of Philopotamus ludificatus in 1906; as I was unable to obtain this paper, however, I will summarize a fuller description which appeared in 1908.

Two similar species P. ludificatus McL., and P. montanus Don., are found in great numbers in the swift mountain brooks of Middle Europe. These build dwellings which are very much alike. The house is a broad sac-like structure of loose mesh about as long as one's finger. At the front end where the opening is found, it is fastened to a stone on the bottom of the brook. The blind end of the sac floats freely; and in the bottom of it is found the larva which can feed on organic particles caught in the net. Occasionally the larvæ also stretch their houses between two neighboring stones and so construct for themselves, in this way, a kind of catching-net. Only one larva is found in each net.

No descriptions have appeared before of nets of the Genus Chimarrha. The nets of Chimarrha aterrima, which I found, are long, narrow pockets built entirely of a very fine mesh of delicate silken threads. (See Plate XXXVIII, Fig. 1). The average size of the net of the growing larva is about 25 mm. long and 3 mm. wide. The nets are rarely found singly, but generally placed five or six in a row. Sometimes the front edges of these are joined together, but in most cases each net is entirely separate from that of its neighbors. There is a large opening at the end facing the current, and a tiny opening at the hinder end just large enough for the larva to slip through and make its escape when alarmed. This opening is very hard to see, not only because of its size, but owing to the fact that the nets are generally brown with a coating of diatoms, etc., over much of their surface. The nets are fastened at the entrance by their entire lower edge, the rest of the sac floating freely, and kept distended by the current. They are found fastened to the underside of stones or to their upper surface when they are covered by other stones. I have also exposed them on the upper surface of the shelving rocks by pushing aside the covering mats of Cladophora. The orange or yellowish larva, of which there is only one to a sac, is usually seen

toward the hinder part of the net. It does crawl around, however, feeding over the whole surface of the net. It does not use its front legs to assist it in getting its food which is entirely of microscopic plants. All observations must be carried on in swift water, for the net collapses into a brown slimy mass when the pressure of the current is removed. The separate threads of the net are only clearly seen with the highest power of the microscope when it is seen that the units of the mesh are rectangular in shape, one dimension being about eight times the other. The double nature of the silken threads is not recognizable, as is that of the Hydropsyche's, when examined with a microscope.

At times grains of sand and small pebbles are found on and about the large nets. I believe this to be a preparation for pupation, as the pupal cases are constructed of these.

Family Polycentropidæ.

The nets of five genera in this family have been observed and described.

Neureclipsis.

In the year 1900 Wesenberg-Lund first noticed the plancton-catching-nets of Neureclipsis bimaculata in Western Jutland. Later he also found them at three different places in Zealand. They were not described, however, until 1907 when E. Petersen wrote an account of them. His observations were extended by Wesenberg-Lund (1911). The nets of this larva are trumpet-shaped, from 69 to 90 mm. long; the expanded mouth is 25 to 35 mm. broad, and the hinder end about 10 mm. In some cases the hinder end of the tube is attached to some object, in other cases it floats freely. The nets show a regular variation in color due to the plancton caught in their meshes; in the spring they are brown or grayish from diatoms, in the summer bluish-green from the Cyanophyceæ. The net is kept distended by the force of the current and collapses into an unrecognizable mass when taken from the water. The plancton-organisms Bosmina, Daphnia and the remains of Cyanophyceæ become caught in its walls as the water filters through and serve as food for the larva which is generally at the hinder end of the net. Many thousands of these nets span the stream in Hennebach so that a greater part of the water filters through them.

These writers believe that the imago probably lays her eggs in loose, web-like masses which are doubtless a conglomeration of old nets and that the young larvæ live together in them for a long time.

Plectrocnemia.

Miall (1895) gives a description of a Plectrocnemia net written by Mr. T. H. Taylor. "Plectrocnemia finds its home in streams where the water flows swiftly over a stony bed. If a stone be lifted out, the under side is often found to be covered with patches of mud from which brown larvæ emerge and begin to crawl over the surface. The muddy particles are evidently held together by some binding substance, and the whole forms the retreat of the Caddis-worms, corresponding to the cases of Phryganea. When a larva is placed in a vessel of clear water, it at once begins to explore its new quarters, and eventually selects a site for its dwelling. This is made of silken threads secreted by the large silk glands, and when completed the structure consists of a tube considerably longer and broader than its occupant and open at both ends. It is supported and strengthened by a meshwork of silken threads, which spread out for a considerable distance, and are attached to the surrounding objects.

From time to time the larva turns round in its case and even leaves it for a short space. Generally, however, it remains quiet inside, apparently on the alert for prey. If a Chironomus or other small aquatic larva approaches, it is almost certain to get entangled in the network of silken threads. At once the Caddis-worm in its retreat perceives the presence of a possible victim. The long hairs which cover the body are possibly tactile, and receive slight disturbances of the silken network. The Plectrocnemia then proceeds warily to determine the cause of the disturbance. Should the Chironomus be entangled near the middle of the tube, the Caddis-worm does not hesitate to bite its way through the side, and its jaws very soon quiet the struggles of the prey.

There is some resemblance between the snare of the Plectrocnemia and the web of a spider, but the Plectrocnemia is effectually concealed by the mud which clings to its retreat."

The net of Plectrocnemia conspersa Curt. is described by Wesenberg-Lund (1911). The larvæ—at least from April until

June—build large, flat catching-nets about a square decimeter in size. In the centre is an opening, (about 8 to 10 mm.,) which leads into a funnel about 5 to 6 cm. long—the hiding place of the larva. This is hidden under a stone or leaf. The mesh is very coarse on the outer edges of the net. The water being very shallow in the brook, the nets lie nearly horizontally on the stones. The organisms caught in the nets by the larvæ are principally gnat-larvæ, Asellidæ, etc., which are swept along by the stream into the net.

Polycentropus.

The net of Polycentropus flavomaculatus Pict. was first described and figured by Petersen (1907). The nets resemble swallows' nests and are about 30 mm. long, 20 mm. wide at the entrance, and about 15 mm. high. They are found singly on the bottom of slowly flowing brooks attached by their fore corners to small stones. The mouths face the current and are held expanded by the water. The larvæ are always found in the bottom of the net. When found on vertical banks, the mouths stand perpendicularly. The nets are also found on the wave beaten shores of the larger lakes. The nets are bluish-green in color.

Holocentropus.

The larvæ of the genera Holocentropus and Cyrnus live in quiet water, principally among algæ and water plants of the smaller lakes and pools. The nets, which are hard to observe, have been completely overlooked before Wesenberg-Lund's paper (1911). He first saw the net in June 1909.

He figures three forms of nets which he found made by Holocentropus dubius. One type of net is in the form of a shallow funnel attached by silken threads to Sium leaves. In the centre is an opening which lands into a thick web-like tube which extends to the main stem of the plant. In this passage the larvæ live and may escape through an opening at the hinder end. The second type is found where there are thick mats of filamentous algæ, as Spirogyra. In this loose mass may be seen perpendicular tunnels 8 to 10 cm. long, covered with spinning; these are open below and also open at the surface in the middle of a shallow funnel-like net of very fine mesh. The larvæ sit at the bottom of the funnel-like recess

watching for prey. There is often at least one side passage branching off from the main tunnel. Another type is a funnel-like net spun between the angles of the main stalk of the grasses and the side shoots, and fastened at the upper end to leaves as Potamogetons.

On account of lack of light the study of the nets of Holocentropus picicornis Steph. was unsatisfactory. The deep brown color of the nets was due to a thick deposit of iron bacteria.

The larva of Cyrnus flavidus McLach. lives in lakes in the Chara-and Elodea-zone at a depth of about 4 m. In summer the larva spins funnel-shaped nets to the leaves of Potamogeton lucens when it reaches the surface. In the autumn long threads emerging from the plants are seen floating about in every direction. Plancton organisms become entangled in the threads and the larva runs along these and siezes its prey. In October and November the larvæ sink down with the Potamogeton on to the Elodea and Chara zone again.

In a little arm of Cascadilla Creek (See Plate XXXVI, Fig. 1) where the water is rather quiet and from 1½ to 2 feet deep, larvæ of two genera are found belonging to this family.

The larva of Cyrnus pallidus (?) is small—8 mm. long by 1.2 mm. broad—very rapid in its movements. The body is whitish, dorso-ventrally flattened; the head yellowish with a large brown spot covering almost the whole dorsal surface. In the centre of this spot is a yellow cross-shaped figure and eleven yellow dots around the margin. The yellowish pronotum is brown posteriorly with yellow dots. On removing a stone from the water the dwellings of this larva might easily be overlooked, for they resemble patches of sediment clogging the crevices. If placed in a pan of water, however, and examined under the microscope, they prove most facinating objects for study. Stretched across crevices in the stones, preferably along its edges, but also occasionally on the upper and lower surfaces is the roof of the larval dwelling. The tube of a full grown larva, is about 9 mm. long by 3 mm. broad and is dorsoventrally flattened. (See Plate XXXVIII, Fig. 2). It is spun of fine silken threads so closely woven that it has a felty texture. It is always brown with a coating of diatoms. At either end a little flap hangs from the roof which acts as a

stopper, closing against the opening when the stone is removed from the water. Radiating in all directions from the floor of its retreat, at either end, may be seen threads of silk about 7 mm. long. These are fastened to the stone at their outer ends and a microscope reveals the fact that they are connected with one another by a loose irregular mesh which floats up from the surface of the stones and entangles many small organisms. The larva lurks in its little cave, and welcomes visitors gladly at its front or back door. Any movement on the silken strands in front of its doors causes it to dart out the front part of its body with lightning-like rapidity, sieze the intruder and draw back again, all in the twinkling of an eye. Large numbers of Vorticella and other Ciliates, rotifers, Chaetonotus, Chironomids and diatoms were found entangled in the meshwork.

The larva of the Polycentropus sp. (?) is large and more deliberate in its movements. It is 19 mm. long and 2 mm. broad; the head and prothorax yellowish-brown with many small, brown dots, and the abdomen of a pinkish-lavender color, iridescent when the sunlight strikes it. It sometimes looks bluish. The larva lives on the under side of stones in a delicate silken dwelling which falls together into an unrecognizable, brown slimy mass when removed from the water. It was not until I had examined a large number of these nets that I was able to detect a trace of any definite form. The larva lives in a very delicate, silken tube fastened to the stones along its whole undersurface. It is shaped like a flattened cylinder and slightly curved. (See Plate XXXVIII, Fig. 3). The tube is 21 mm. long and 5½ mm. wide with an expanded opening at either end. Connected with each opening and along either side is a mass of tangled, silken threads, about 20 mm. square and loosely attached to the stone. This tangled mass may float partially over the tube and so obscure it.

I have never observed the larva feeding but do not doubt that Mayfly nymphs and Chironomid larvæ become entangled in the meshes as they crawl about over the stones, for remains of these forms are abundant in the stomach contents.

III. The Aquatic Situation.

All of my collecting and observations on the net-spinning Trichoptera were confined to a very limited area in Cascadilla Creek, not exceeding a half mile in extent. For a preliminary study this presented advantages, one of the most important being an abundance of material within a few minutes walk from the laboratory. This made it possible to observe conditions frequently and to spend more time in the field than would have been possible had the Creek been at a distance. The use of the Fish Hatchery, situated on the bank of the Creek, also offered opportunities for studying things to the best advantage, for all necessary equipment as microscopes, instruments and glassware could be kept there. It also furnished a place where rearing and experimental work might be carried on, undisturbed and under natural conditions.

The depth of the Creek varies from a few inches, where it spreads over the large, flat rocks, to two and a half feet or more in the middle of the stream. The creek-bed averages from ten to fifteen feet in width but broadens out in places to thirty feet or more, where the larvæ abound, the bottom is rocky and of two types—loose stones, both large and small, (See Plate XXXVI, Photo 1), and continuous shelving rocks with gradual descents of a few inches to steep descents of five feet or more. (See Plate XXXVI, Photo 2). In early spring and fall the water rushes along in torrents over the rocks, but by midsummer the swift water is confined to the middle of the creek-bed. Large areas of the broad, shelving rocks remain dry and where there is water it does not exceed an inch in depth.

Most of the typical swift-water forms of insect nymphs and larvæ were found associated with the Hydropsychids. Of the Trichoptera, Rhyacophila, Helicopsyche, Silo, and a Hydroptilid sp.; of the Diptera, Simulium, Chironomid and Blepharocera larvæ were very abundant on the upper surface of the stones; of the Mayflies and Stoneflies, the nymphs of Heptagenia, Chirotonetes and Neoperla were found in numbers on the under side of the stones. The rocks presented various colors—the browns of diatom ooze, large black patches of Simuium larvæ, and in places thick green carpets of Cladophora. The swift water and great abundance of food made it an ideal situation for the larvæ.

IV Food.

In most of the literature one finds the larvæ of the old family Hydropsychidæ spoken of as carnivorous, but Siltala (1907) gives the following general statements. "The larvæ of the true Hydropsychidæ are less exclusively carnivorous than those of the other campodeoid larvæ. Both animal and vegetable food are found, remains of insects, Crustacea, algal filaments, pieces of moss and phanerogam leaves, also pollen grains of Conifers." In an earlier paper (1910) he speaks of their ability to utilize hard vegetable stuff, gnawing grooves nearly 8 cm. deep in the logs of a bridge.

"The data were insufficient in the case of the Family Philopotamidæ to form any judgment. The Polycentropidæ are purely carnivorous, eating insects, Cladocera and Ostracods."

He also points out that a relation exists between the structure of the mandibles and the kind of food. He extends Ulmer's (1902) observation that forms with blunt-toothed mandibles are herbivorous and those provided with sharp teeth are carnivorous, and points out the importance of the presence or absence on the mandibles of a median tuft of hairs. All forms with the median tuft on both mandibles are herbivorous; those lacking it are either exclusively carnivorous or at least eat as much animal as vegetable food; larvæ with the tuft only on the left mandible vary in respect to their food and among them are found carnivorous, herbivorous and omnivorous forms.

My results in regard to the food of the larvæ are based entirely on observations upon freshly killed animals taken from their natural habitat. The alimentary canal was removed immediately after the collecting trip and examined at once, or placed in four per cent formalin for later study.

Collections of Hydropsyche larvæ were made on November 14, 1912, November 21, November 30, January 31, 1913, February 18, March 20, April 12, May 6, June 2 and July 7. As many as five specimens were always examined, and in some cases as many as ten. The food as stated by Siltala was made up of both animal and vegetable matter. There was, however, a seasonal difference; in the fall and winter diatoms formed the bulk of the food, and in the spring and summer animal food predominated; while at all times algal filaments were present in moderate amount.

Of the diatoms, Gomphonema, Cocconema and Navicula were the most abundant forms, though Synedra, Melosira, Encyonema and Fragillaria appeared in smaller numbers.

Ulothrix and Oedogonium and Cladophora of the green algæ were found all of the year, and in the spring and summer Merismopædia and Cilyndrospermum of the blue-greens appeared.

Heptagenia nymphs, and Chironomus larvæ made up the bulk of the animal food, although Simulium larvæ and Ostracods were abundant. Difflugia shells were found a few times.

These results do not agree with the statements of Wesenberg-Lund (1911) and Ussing (1907) that the larvæ are inactive, lying rolled up in a spiral and taking little or no food in the winter. The collection made in February came at a time when the Creek was covered with ice. The larvæ were found on the underside of stones in the stream, either in a case of pebbles loosely held together or a mass of roots spun into a tubular form. When the stones were removed from the water and placed on the bank, the larvæ came out of their tunnels at once and crawled about over the stones. There was also an abundance of food in the stomach in every case.

In examining the contents of the stomach of Chimarrha aterrima (Family Philopotamidæ) one is greatly surprised to find vegetable food exclusively. The mandibles are strongly developed, with sharp teeth, and lack the median tuft completely, which, according to Siltala, would point to an exclusively carnivorous form. Examinations were made on November 14, November 30, June 11 and July 14. On the first three dates, the stomach contents consisted of diatoms exclusively, the same forms as were found in the Hydropsychids. On the last date, however, Euglena was very abundant, as were the simple green alga Scenedesmus and other Protoccocales; also desmid zygospores. In every instance there was very much silt mixed in with the food.

Only one examination of food was made on the two larvæ of the Family Polycentropidæ. This was on July 14, when ten specimens of each species were examined. The food of Polycentropus sp. was made up entirely of insects, Chironomids being the principal diet, and Heptagenia nymphs quite numerous.

Except for one Chironomid head there were no recognizable contents in the alimentary tract of the Cyrnus sp.—only a dark brown fluid exuded. After watching it feed, however, on the soft bodied forms of microscopic organisms, one can account for this fact.

V. Experimental Work on Hydropsyche Nets.

To one who tries to study the method of construction of the nets, feeding habits, etc., in the field, the following difficulties present themselves. The threads of the net quickly become covered with diatoms, silt and algæ which obscure the mesh to some extent; the ripples on the surface of the water make it necessary to work with a water-glass which cuts out some of the light; also the nets are so low down that one can only view them satisfactorily from above.

Although the Hydropsyche larva will construct its dwelling tube in a dish of water in the laboratory, it builds no catching-net. The larvæ, however, made perfect nets in a trough supplied with a steady stream of partially filtered water from Cascadilla Creek. The trough stood on a framework three feet high and was tilted slightly, the end nearest the water-pipe being the higher. The side boards of the trough were grooved (¼ in. by ¼ in.) their entire length, and the stream of water striking the end board was carried down into the grooves as well as into the trough. On each side, at the point where the water from the groove met the overflow from the trough (See Plate XXXVI, Photo 3.) the current was the swiftest. As might be expected these spots were chosen in preference to others as building sites. The only caution taken was to induce the larva to begin its spinning very near the end of the groove so that the net would come within the focus of a lens held in front of the groove. The making of the larval dwelling could best be observed from above, but observations on the construction of the net and the feeding habits could be seen to best advantage when one knelt in front of the groove so that the eye came on a level with it. In all cases a glass slide was placed over the groove to smooth the surface of the water.

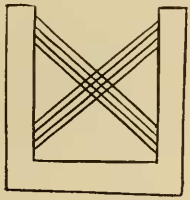
By the above methods, the following results have been obtained.

1. Time of building.—Many Trichoptera larvæ build their dwellings chiefly during the night, but these build their tubes and nets at all times, during the day as well as at night.

2. Time required for building.—On watching the construction of several larval dwellings, I found the average time for the completion of the tube and net to be from two and a half to three hours. The larva spent about an hour in spinning its tube and the remainder of the time on its net.

3. Different species of Hydropsyche larvæ placed in the trough built similar dwellings.

4. There were no temporary construction threads in the net as described for the web of orb-weaving spiders, (Comstock, J. H., 1895, p. 37), all of the threads being permanent.



1

2

Text Figs. 1 and 2. 1. Diagram showing usual method of crossing of threads to form the regular mesh of the net. 2. Attachment of threads. (a) at beginning of thread; (b) continuation of same thread at point of departure from supporting surface.

5. There seemed to be no definite order in which the threads of the net were laid down. Sometimes the coarse, irregular mesh was spun immediately after the building of the larval tube, while at other times the fine, regular mesh was spun first. The larva at times left its work on the net and went back to add a few threads to the case. In general the catching surface was formed of threads crossing each other in the fashion shown in figure 1. Threads were fastened in the manner shown in figure 2, the double thread being split for a short distance and each half attached separately.

6. I have never observed the larvæ cleaning their nets with the dorsal tuft of hairs on the anal prolegs, a function which Lund (1911) stated as a probable one. They have always removed particles from the net with their mouth-parts.

I believe that the thick cluster of bristles on the outer edges of the labrum are used in removing the microscopic plants from the meshes.

7. The larva used its front legs in combination with the mandibles for seizing, and holding in position until fastened with silk, any bits which it might wish to weave into its tube or use as supports for the net.

8. The position indicated in Plate XXXVII, Fig. 5 is the one usually assumed by the larva in spinning its net and in feeding. Since no pebbles or vegetable bits were placed in the groove, the larva spun its tube entirely of silk, and so its position could be clearly seen. The larva rested ventral side up with the hooks of the anal prolegs fastened in the roof of the tube. Usually only the head and thorax protruded from the entrance, but if the larva needed to reach out farther than the stretching of the abdomen would permit, the body was moved forward in the tube. The front legs were directed forward, and were used chiefly for clinging on to the net during its construction. The tarsal claws were passed rapidly along a thread near to the one which was being spun. The second and third pairs of legs were also used for holding on, being stretched out on either side and shifting only as the movements of the larva demanded it.

9. Feeding Habits.—The larva never was so intent upon finishing its net but that it stopped and picked off particles of food adhering to the threads, ate them and then continued its labors. As soon as it finished its net, and while the mesh was practically clean, I put insect food (Simulium larvæ and Heptagenia nymphs) into the groove. One specimen was used at a time, and the net was effective in holding back food as the water filtered through. The larva siezed any intruder almost immediately with its front legs and mandibles and pulled it down toward the mouth of its tube. It was not without a struggle that its victims were subdued, sometimes as long as five minutes being required. The larva seemed to swallow its food whole, with little chewing of it, and shoved it into its mouth with its front legs. Perfect or only slightly mutilated specimens of Chiromid larvæ and Heptagenia nymphs found in the œsophageal region seemed also to point to this method of feeding.

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PLATE XXXVI.

Photos by J. T. Lloyd.

Photo 1. Cascadilla Creek below Fish Hatchery. Taken in midsummer when the water is low to show character of creek bed. Earlier in the season, the Hydropsyche nets stretched between the stones on the bottom are very numerous. In the quiet water at the left the larvae of the Family Polycentropidæ are found.

Photo. 2. Cascadilla Creek in the spring as it rushes over the shelving ledges beside the Hatchery. A favorite spot of the Hydropsyche larvae.

Photo 3. Trough where experiments were carried on. Water entered through pipe above, and spilled over at corners at lower end, through grooves in the sides, where the Hydropsyche larvae built perfect catching-nets. Under the trough is a water-glass used in field work, and beside it, a folding bench for use while making observations in the stream.

PLATE XXXVII.

Fig. 1. Diagrammatic figure of a house of Hydropsyche angustipennis, copied from Wesenberg-Lund (1911) (Plate IV, Fig. 22). At the left is the tube in which the larva lives. In front of it is a vestibule with a catching surface of fine mesh in its side wall. Near this net is the opening of the larval tube.

Fig. 2. A typical Hydropsyche dwelling in which the coarse, irregular meshwork of the net is not strengthened by any supporting bits. Enlarged x 2.

Fig. 3. End view of one of the grooves of the trough with the Hydropsyche dwelling built in it.

Fig. 4. Hydropsyche dwelling built in trough, and viewed from above.

Fig. 5. Usual position assumed by the Hydropsyche larva in spinning its net or in feeding.

PLATE XXXVIII.

Fig. 1. Catching-net of Chimarrha aterrima. Natural size.

Fig. 2. Dwelling of Cyrnus pallidus (?). Larva lives in the tube, and at either opening is the catching-net. This is composed of radiating strands of silk fastened at their outer ends to the stone, and connected with one another by an irregular mesh. Enlarged x 2.

Fig. 3. Dwelling of Polycentropus sp. (?) Delicate silken tube in which larva lives, slightly curved, and surrounded on all sides by a delicate irregular mesh which functions as a catching-net. Enlarged x 2.